

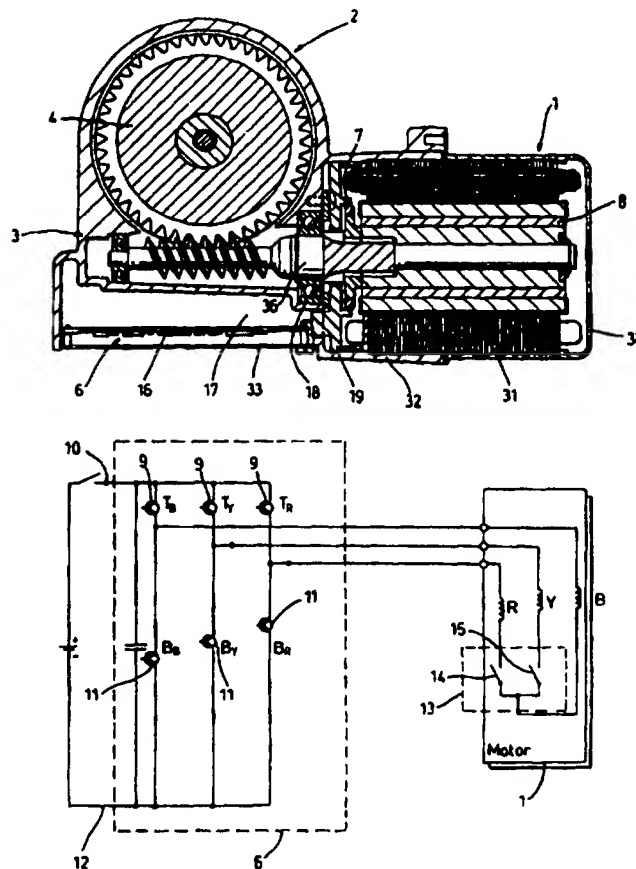
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(54) Title: ELECTRICAL POWER-ASSISTED STEERING SYSTEMS

## (57) Abstract

An electrical power-assisted steering system is disclosed comprising a brushless electric motor (1) which has a plurality of phase windings connected at a star point and in which a switching means (13) such as a relay is provided in at least one phase of the motor, the switching means being movable between a closed position in which current is able to flow in the phase winding and an open position which prevents current flowing in the respective phase in the event of a fault. Also disclosed is a substantially rigid connector assembly (19) onto which is mounted the switching means (13), conductors (20) for connecting the motor phase windings and a motor position sensor (21) to an associated motor control means (6), the connector acting as a support for the motor stator, which simplifies the steps involved in assembly. In another aspect of the invention, the electrical power assisted steering system includes a one-piece casing (3) which acts as a housing for the gearset, torque sensor, control means and at least part of the motor.



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## ELECTRICAL POWER-ASSISTED STEERING SYSTEMS

This invention relates to an electrical power-assisted steering system for a vehicle of the kind comprising an electric motor connected  
5 through a gearbox to act on a steering mechanism of the vehicle. For example, the gearbox may provide a connection between the motor and a steering column shaft, or directly onto a portion of a rack and pinion mechanism forming part of the steering mechanism.

10 The electric motor is used to assist a driver in applying torque to the steering mechanism, by applying an assistance torque of the same sense, to make it easier to turn the steering wheel, for example during parking manoeuvres. Thus, operation of the motor may assist in rotating the steering column shaft, or moving a portion of the steering rack  
15 mechanism. Of course, the motor may be connected to any part of any typical steering mechanism as long as it can provide an assistance torque to aid the driver in turning the steering wheel.

The motor, which may be a multi-phase brushless star-connected  
20 permanent magnet motor, is controlled by motor control means comprising control and drive circuits, which is operative to supply a current from a power supply to the motor phase windings. The phase windings of the motor are connected at a star point. Each phase is connected to a positive terminal of the power supply by a top transistor,  
25 and to a negative terminal by a bottom transistor, the two transistors defining an arm of a multiple arm bridge. This bridge forms the drive circuits, while the control circuits are provided by a microprocessor or digital signal processor or analogue signal processing or some combination thereof. The microprocessor is operative in response to  
30 signals from a torque sensor provided on the steering column to measure

the torque applied by the driver, from a motor rotor position sensor providing information about motor speed and direction and optionally from signals corresponding to current flowing in the motor bridge or power supply. This information can be used in combination with the torque sensor signal and/or column position sensor signal to determine which phase winding should be energised and when. The microprocessor produces control signals which energise the transistors of the drive circuits to cause current to flow in a desired motor phase.

10 A problem with this electrical power-assisted steering system is that a fault occurring in the motor drive or control circuits can cause an error condition which is unacceptable in a vehicle steering system, where safety is critical.

15 For example, suppose that a top transistor in one arm of the bridge is energised in error while a bottom transistor in another arm of the bridge is also energised in error. This fault would result in a phase of the motor becoming permanently energised and cause the motor to become permanently attracted to a particular position, tending to clamp the steering column in position and resist rotation. This would be readily apparent to the driver, and is clearly undesirable. This situation could occur if the microprocessor is at fault, or if a short circuit occurs across the transistors.

25 One known solution to this problem is to provide a clutch between the motor and the steering column. The clutch, typically a dog or friction clutch, is normally engaged but in the event of a fault being detected, the clutch is operated to disengage the motor from the steering column. However, the clutch is costly and bulky, and additional test procedures must also be incorporated to check that the clutch can still be disengaged

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should it be necessary to do so, which again adds to the cost and is time-consuming.

Another solution is to provide a means for isolating the motor drive  
5 circuitry from the power supply in the event of a failure, for example by  
providing a relay between the supply positive terminal and the drive  
circuitry. This removes the drive current from the motor but is not  
without its problems. Because the phase windings are still connected  
together and connected to the drive circuitry, an electrically conducting  
10 path could still be present around the bridge (i.e. through two short  
circuited transistors and two phase windings). Then, on rotation of the  
motor shaft drive due to rotation of the steering column, a back EMF is  
produced in one or more of the windings. As a result of this EMF and the  
complete electrical path around the bridge, a substantial current can flow  
15 through the motor phase windings which produces a torque in the opposite  
sense to the rotation of the motor shaft. This resisting torque is highly  
undesirable because in this case, not only is steering assistance lost due to  
disconnection of the power supply, but a resisting torque is then applied  
which makes turning the steering column difficult.

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In accordance with a first aspect of the present invention, in an  
electrical power-assisted steering system for a vehicle of the kind set  
forth, the electric motor is a brushless motor having a plurality of phase  
windings connected at a star point, and a switching means is provided in  
25 at least one phase of the motor, the switching means being movable  
between a closed position in which current is able to flow in the phase  
winding, and an open position which prevents current flowing in the  
respective phase winding of the motor.

The switching means ensures, if a fault condition arises, that the motor does not provide a resisting torque to the movement of the steering column because no current flows in the phase winding. This means that no clutch is required. Secondly, the switching means, when open,  
5 prevents the back EMF generated by the movement of the motor rotor from producing a current in the winding as the phase is connected to an open circuit and so no current can flow. This is true regardless of the nature of the fault in the motor or the drive circuitry.

10 Preferably, the switching means comprises a switch or relay which is connected in series between an end of the phase winding and the motor drive circuitry. Alternatively, the switching means may comprise a switch or relay which is provided at the star point of the motor and opening of the switching means isolates the phase winding from the star  
15 point.

A separate switching means may be provided in each phase of the motor to allow each phase to be isolated from the star point independently. The switching means may comprise a solid state relay, but  
20 any suitable isolating switch could be used.

In a preferred embodiment, the electric motor comprises a 3-phase motor and the switching means comprises a pair of relay contacts operated by a single relay coil so that two of the three phases can be isolated from  
25 the third phase which is common to both relay contacts.

A further problem with electrical power-assisted steering systems of the kind set forth arises due to the need to connect the motor phase windings to the motor control means and power supply.

30

In order to reduce bulk, cost and EM radiation emissions an electrical power-assisted steering system requires that the drive circuitry, motor and gearbox are housed in close proximity to each other. In one known system the drive circuitry is mounted onto a printed circuit board (PCB) which is then fixed near to the motor, for example inside the gearbox housing. The motor windings are then connected to the PCB using flying leads. However, flying leads are undesirable because they can become tangled up with a rotary part of the motor or gearbox due to the confined space, and they are time consuming to connect. The provision of the relay to isolate phase windings, where required, also imposes problems of mounting and adds to assembly time as it requires extra leads.

In accordance with a second aspect of the present invention, in an electric power assisted steering system of the kind set forth, a connector assembly connects the electric motor to an electronic circuit, the connector assembly comprising a substantially rigid frame which is adapted to support a plurality of conducting tracks which provide a connection between phase windings of the motor and the electronic circuit.

By providing the rigidly supported conducting tracks as a connector assembly between the motor winding and the electronic circuitry, the problems associated with loose flying leads are eliminated. In particular, the rigid support of the tracks means that it is possible to position the tracks close to the moving parts of the motor and gearbox without fear of contact between the two. Assembly time is also reduced as it is possible to connect the tracks to the motor phase windings and then to the electronic circuitry in a simple manner.

The conducting tracks may be substantially rigid in their own right, or may be flexible but rigidly supported by the rigid frame. The tracks may also have legs which project out of the rigid frame to facilitate direct connection with the electronic circuitry which is sited remotely from the  
5 motor.

Preferably, the electronic circuit comprises the motor control means, comprising the drive and control circuits which are housed within a first portion of a gearbox housing and the connector assembly and motor  
10 are accommodated at least partially within a second portion of the gearbox housing. In this case the legs of the conducting tracks are adapted to protrude through one or more openings provided in a wall of the gearbox housing so as to allow connection to the control circuitry. Most preferably, at the point where the legs of the conducting tracks pass  
15 through the openings they are surrounded by an insulating portion of the rigid frame to prevent accidental electrical contact with the housing wall. The rotor can protrude through a further opening in the wall of the housing for engaging with the gears contained in a third portion of the gearbox housing. A lid may be provided for sealing the PCB in the first  
20 part of the housing after assembly.

The rigid frame and conducting tracks may be in the form of a lead frame or may comprise a printed circuit board. Alternatively, a multiple layered printed circuit board may be used. The rigid frame could be of an  
25 electrically insulating material such as a plastics material, and may be moulded.

The rigid frame may also act as a support for the motor stator, to assist in securing or locating the motor to the housing. This could be  
30 achieved by providing engagement means on the frame which cooperates



with complementary engagement means on the motor to ensure correct alignment between the motor and the conducting tracks.

The rigid frame may also provide a mounting for a motor rotor  
5 position sensing means, which, for example, may comprise a plurality of Hall effect sensors which detect the magnetic field of the motor rotor. Because the motor stator position can be fixed relative to the rigid frame, the correct position of the sensors relative to the stator can be assured. The frame provides a simple way of mounting the sensing means  
10 accurately.

It is also advantageous for the connector assembly to provide a mounting for a switching means (i.e. a relay) which is used to isolate the motor phases in the event of a motor failure. This enables the relay to be  
15 provided close to the motor phase connections, ensuring low resistance and minimising path lengths to increase safety. Again, the conducting tracks for connecting the relay to the phase windings can be provided on the connector assembly.

20 In a preferred embodiment, the connector assembly comprises a moulded rigid frame of a substantially cylindrical form, and is secured to the gearbox housing to be arranged substantially concentrically with a circular cut-out in the side of the gearbox housing. When in position, the rigid frame lies entirely within the second portion of the gearbox housing.  
25 The rigid frame is prevented from rotation within the second portion by lugs provided around its perimeter. On a face of the rigid frame opposite to the face on which the motor is secured, the conducting tracks for the phase windings and the conducting tracks for the rotor position sensor are formed into the legs which project axially away from the motor to pass

through openings in the gearbox housing into the first portion of the housing for connection to the PCB carrying the drive and control circuits.

According to a third aspect of the present invention, an electrical  
5 power-assisted steering system of the kind set forth includes a one-piece housing accommodating at least a part of the electric motor, electronic circuits adapted to control and drive the electric motor, a connector assembly having conducting tracks connecting the motor to the electronic circuits, the gearbox and a torque sensor.

10 The one-piece housing is especially suitable for use with a connector in accordance with the second aspect of the invention, as there is no need to provide routing for flying leads as in the prior art.

15 The housing may be of metal or plastics material. Preferably, the housing comprises three integral portions; a first portion which houses the electronic circuits, a second portion which houses at least part of the motor (ie the stator and/or armature) and a connector assembly, the second portion being sealed with an end cap, and a third portion which  
20 houses the gearbox and the torque sensor. The second portion may form at least a part of the casing for the electric motor, eliminating the need for a separate motor casing.

The one-piece housing provides a compact, low cost housing for all  
25 the essential components of the electrical power-assisted steering system. Furthermore, because the torque sensor is accommodated in the housing, the number of separate components is reduced. The torque sensor may also be provided with a connector assembly. The first, second and third portions may define cavities which accommodate various parts of the  
30 electrical power steering system to isolate the parts in one cavity from

those in another. For example, this provides shielding of the electronic circuits in one portion of the housing from the motor which is housed in another portion of the housing.

5           The second and third aspects of the invention mean that the construction and the assembly of the motor, gearbox and electronic circuit can be greatly simplified. For assembly, the motor stator is secured to the rigid frame. The frame and motor stator are then pressed into the second part of the gearbox housing with the conducting tracks protruding  
10 into the first portion of the housing. The rotor can then be inserted through the stator to pass through the hole in the wall of the housing to engage the gearbox in the third portion of the housing. The torque sensor is also inserted into the housing. Finally, the control and drive circuit PCB is inserted into the gearbox housing so that the conducting tracks  
15 align with the tracks on the PCB, and the tracks are soldered together to complete the circuit. It will thus be appreciated that the efficiency of assembly is greatly improved. Because the PCB, gearset and motor are all contained within separate portions of the housing, electromagnetic immunity is good and the circuits are well protected from environmental  
20 effects.

There will now be described a preferred embodiment illustrating the various aspects of the invention, with the aid of the following drawings, in which:-

25

**Figure 1** shows a part of a EPAS system having a motor to which the present invention is applicable;

**Figure 2** is a partial circuit diagram of an electric motor and its associated drive circuitry which is in accordance with a first aspect of the present invention;

5       **Figure 3** is a view of the gearbox housing, electric motor and the connector assembly supporting the conducting tracks after assembly of the system;

10       **Figures 4 and 5** are two different views of a connector assembly in accordance with the second aspect of the present invention;

15       **Figure 6** is an illustration of the layout of the conducting tracks carried by the rigid frame of the connector assembly and the connections from the tracks to the relay and motor phase windings;

**Figure 7** is a view of several possible terminal posts which can be formed on the end of the conducting tracks;

20       **Figure 8** is a view of the gearbox housing and connector assembly prior to assembly; and

**Figure 9** shows an exploded view of a complete electrical power assisted steering assembly using the one-piece housing of the third aspect of the invention.

25

**Figure 1** illustrates a part of an electrical power-assisted steering (EPAS) system for use in a vehicle. The system shown comprises a three-phase brushless permanent magnet DC motor 1 which is connected via a gearbox gearset 2 housed in a one-piece housing 3 to a steering column 4.

30   A torque sensor (not shown in Figure 1) provided on the input side of the

steering column 4 provides a measure of the torque applied by the driver of the vehicle, and the output from the torque sensor is used to control the electric motor via a motor control means including a control circuit and drive circuit 6. In addition to the torque sensor, a motor rotor position  
5 sensor 7 is provided which comprises a set of three Hall effect sensors which can detect the position of the magnetic rotor 8, or the position of magnets mounted on the rotor.

Figure 2 illustrates the electrical equivalent circuit of the brushless  
10 motor 1 and the drive circuit 6. The drive circuitry comprises a three phase bridge, with each phase of the bridge having a top transistor 9 connected between the first end of a respective phase winding (R,Y,B) and a positive supply terminal 10, and a bottom transistor 11 connected between the first end of the respective phase winding and a negative  
15 supply terminal 12. Each of the transistors is shown as a single power transistor, which may be of the FET or bi-polar type. The transistors are energised or de-energised by an electronic drive circuit (not shown) in response to signals generated by a micro controller (not shown) which receives the output signals from the torque sensor and motor position  
20 sensor 7.

In this embodiment a relay unit 13 is provided at the star point of the electric motor. The relay unit as illustrated has two contacts 14,15 driven by a single relay coil although the relay unit may comprise two  
25 discrete relays each with its own coil to allow independent control of each phase winding. Normally, the relay is opened so that all the phases are connected together at the star point.

In the event that a fault is detected which would lead to incorrect  
30 operation of the electric motor, the relay is de-energised and the contacts

are opened so that each of the phase windings is isolated from each other phase winding and from the winding that is common to the relay contacts. This prevents back EMF generated by movement of the steering column (and hence motor rotor) from finding a low impedance path through the control circuit and prevents electrical damping from arising.

Also shown in Figure 1 is a connector assembly which is in accordance with the second aspect of the invention. The motor control means 6 for driving the motor is provided on a PCB 16 which is accommodated within a first portion 17 of the one-piece gearbox housing 3, and the motor is provided on the outside of the first portion of the gearbox housing with the motor output shaft operating within bearings 18 keyed to the gearbox housing for stability. This arrangement of components has been found to be advantageous because it results in a low overall size and ensures that the distance between the control circuitry and the motor stator is minimised.

Located between the electric motor 1 and the gearbox housing is a connector assembly 19 which comprises a rigid support for the electrical connections 20 between the motor 1 and drive circuitry. The connector assembly 19 is preferably in the form of a PCB or a lead frame (i.e. a set of conductors held together and located in their environment by a plastics moulding).

Figures 4 and 5 illustrates a preferred embodiment of the connector assembly. The connector assembly serves as a mounting for the motor rotor position sensors 21 which fit in recesses 22 moulded into the frame and can incorporate a shielding ring of material (not shown) which helps to isolate the Hall effect sensors from external electromagnetic interference.

The connector assembly 19 also provides support for the electric motor 1 and its stator windings. The rigid frame includes engagement means 23 which helps to ensure accurate alignment of the motor rotor position sensors relative to the stator windings. The connector assembly 19 also supports the relay 13 which is in accordance with the first aspect of the invention.

Figure 6 illustrates the electrical conducting track arrangement of the connector assembly 19. The tracks 24,25,26,27,28,29 provide a connection between the motor phase windings, the relay 13 and they are arranged on the rigid frame so as to have the shortest path length possible to minimise resistance. The ends of the tracks which connect to the motor phase windings are formed into termination posts by bending the tracks. Figure 7 shows a variety of possible types of terminal post 37 which can be formed. The motor phase windings, which typically comprise several strands of varnished copper wire that is wound around stator poles can typically be connected to the posts by wrapping, soldering or welding.

The recesses 22 provided on the connector assembly retain magnetic sensors 21 that detect the direction of the magnetic field of either the rotor magnets or a set of dedicated sensor magnets attached to the motor rotor shaft, and the connector assembly provides a support for the associated sensor wiring by way of conducting tracks similar to those used to connect to the motor windings.

As mentioned previously, the relay 13 is also mounted on the connector assembly 19. It is preferable to mount the relay on the connector assembly as close as possible to the motor phase winding terminals because this offers a compact arrangement, the elimination of

the requirement for external connections which enhances safety, and a minimised conductor length offers a low resistance.

5 The connector assembly of the preferred embodiment therefore comprises a substantially rigid plastics moulding which supports termination posts for the phase windings, mounting locations for the position sensors, a mounting location for the isolating relay and conducting paths from the windings to the relay, from the windings to the control circuitry and from the sensors to the control circuitry.

10

In order to facilitate connection between the phase windings and sensors and the control and drive circuitry, the conducting tracks 20 are formed at one end into legs which extend away from the main body of the connector assembly and are terminated with individual upturned legs 37 as shown in Figures 5 and 6. The motor phase conductors (high current) and the sensor conductors (low current) are split into two groups.

15

The method of assembly of the motor, connector assembly 19, torque sensor 34 and electrical circuitry 6 with the gearbox housing 3 will now be described with reference to Figures 8, 9 and Figure 1.

20

Initially, the motor stator windings are connected to the terminal posts provided on the connector assembly. The motor rotor position sensors are also put in place in the recesses, and the stator assembly is fixed to the connector assembly. Engaging lugs on the connector assembly co-operate with recesses on the motor stator assembly (not shown), and this ensures that the stator is correctly located relative to the sensing elements.

25



The connector assembly 19 and motor stator 31 are then inserted into a second portion 32 of the gearbox housing 3, and are fixed in place by a bolt (not shown) which protrudes through the rigid frame of the connector into a captive thread in a wall of the gearbox housing. In this position, the conducting tracks protrude through openings in the gearbox housing as shown in Figure 9. The motor armature 35 and shaft 36 are then inserted into the motor stator 31 until a worm gear on the end of the rotor 36 engages with a gear wheel in the gearbox housing 3. Finally, the electronic circuitry 6, which is provided on a separate PCB 16, is secured inside the gearbox housing 3 in a position so that the legs 37 on the end of the protruding terminal portions of the conducting tracks 20 of the connector assembly 19 pass through holes in the PCB. Connection between the PCB and the conducting tracks can then be achieved by directly soldering the terminal portions on the extended legs onto the tracks on the PCB to make the circuit complete. A motor end cap 30 can then be mounted around the exposed end of the motor to form a seal, and the lid 33 placed on the first gearbox portion to seal the electronic circuitry from the external environment if desired.

To summarise, the connector assembly 19 comprises a lead frame assembly which provides a rigid support for electrical conductors 20, a motor fault relay 13 and a motor position sensing means as well as providing a support for the electric motor 1 so that structurally the motor 1 and gearbox housing 3 form an integrated unit. This arrangement is preferred because it is compact, low-cost, reliable and minimises electrical resistance. It is compact because no additional connector blocks are required. It is low-cost because the rigid frame can be extended cheaply and no other components are required. It is reliable because the number of interfaces between the motor windings and the electronic drive circuitry and between the low current signals from the sensors and the

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control circuitry are minimised. Furthermore, all connections are mechanically robust, and the connection distances are short.

It will be appreciated that the switching means (the relay 13) of the  
5 first aspect of the invention could be used in electric motors used in other systems, where appropriate.

## CLAIMS

1. An electrical power-assisted steering system for a vehicle comprising an electric motor connected through a gearbox to act on a steering mechanism of the vehicle, in which the electric motor (1) is a brushless motor having a plurality of phase windings (R,Y,B) connected at a star point, and characterised in that a switching means (13,14,15) is provided in at least one phase of the motor, the switching means (13,14,15) being movable between a closed position in which current is able to flow in the phase winding (R,Y,B), and an open position which prevents current flowing in the respective phase winding of the motor.
2. An electrical power assisted steering system according to claim 1, characterised in that the switching means comprises a switch or relay which is connected in series between an end of the phase winding (R,Y,B) and the motor drive circuitry (6).
3. An electrical power assisted steering system according to claim 1 or claim 2, characterised in that which the switching means is provided at the star point of the motor (1) and opening of the switching means isolates the phase winding from the star point.
4. An electrical power assisted steering system according to any preceding claim, characterised in that the switching means comprises a solid state relay (13).
5. An electrical power assisted steering system according to any one of claims 1 to 4, characterised in that a switching means is provided in

each phase (R,Y,B) of the motor (1) to allow each phase to be isolated from the star point independently.

6. An electrical power assisted steering system according to any one of claims 1 to 4, characterised in that the electric motor comprises a 3-phase motor and the switching means comprises a pair of relay contacts (14,15) operated by a single relay coil so that two of the three phases (R,Y,B) can be isolated from the third phase which is common to both relay contacts (14,15).

10

7. An electrical power assisted steering system for a vehicle comprising an electric motor connected through a gearbox to act on a steering mechanism of the vehicle, characterised in that a connector assembly (19) connects the electric motor (1) to an electronic circuit, the connector assembly (19) comprising a substantially rigid frame which is adapted to support a plurality of conducting tracks (24,25,26,27,28,29) which provide a connection (20) between phase windings of the motor (1) and an electronic circuit.

8. An electric power assisted steering system according to claim 7, characterised in that the conducting tracks are substantially rigid.

9. An electric power assisted steering system according to claim 7, characterised in that the conducting tracks are flexible but rigidly supported by the substantially rigid frame.

10. An electric power assisted steering system according to any one of claims 7 to 9, characterised in that the tracks have legs (37) which project out of the rigid frame to facilitate direct connection with the electronic circuit.

11. An electric power assisted steering system according to any one of claims 7 to 10, characterised in that the electronic circuit comprises the motor control mean, comprising drive and control circuits which are  
5 housed within a first portion (17) of a gearbox housing (3) and the connector assembly (19) and motor (1) are accommodated at least partially within a second portion of the gearbox housing.

12. An electric power assisted steering system according to claim 11,  
10 characterised in that the legs (37) of the conducting tracks (24,25,26,27,28,29) are adapted to protrude through one or more openings provided in a wall of the gearbox housing.

13. An electric power assisted steering system according to claim 12,  
15 characterised in that at the point where the legs (37) of the conducting tracks pass through the openings they are surrounded by an insulating portion of the rigid frame to prevent accidental electrical contact with the housing.

20 14. An electric power assisted steering system according to any one of claims 11 to 13, characterised in that a lid (33) is provided for sealing the connector assembly (19) in the first part of the housing (3) after assembly.

15. An electric power assisted steering system according to any one of  
25 claims 7 to 14, characterised in that the rigid frame and conducting tracks are in the form of a lead frame or a printed circuit board.

16. An electric power assisted steering system according to any one of claims 7 to 14 characterised in that the rigid frame and conducting tracks  
30 are in the form of a printed circuit board.

17. An electric power assisted steering system according to claim 16, characterised in that the printed circuit board comprises a multiple layered printed circuit board.

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18. An electric power assisted steering system according to any one of claims 7 to 17, characterised in that the rigid frame acts as a support for a stator of the motor.

10 19. An electric power assisted steering system according to any one of claims 7 to 18, characterised in that engagement means are provided on the rigid frame which cooperates with complementary engagement means on the motor.

15 20. An electric power assisted steering system according to any one of claims 7 to 19, characterised in that the rigid frame provides a mounting for a motor rotor position sensing means.

20 21. An electric power assisted steering system according to any one of claims 7 to 20, characterised in that a mounting is provided on the connector for a switching means which is adopted to isolate the motor phases in the event of a motor failure.

25 22. An electric power assisted steering system for a vehicle comprising an electric motor connected through a gearbox to act on a steering mechanism of the vehicle characterised by a one-piece housing (3) accommodating at least a part of the electric motor (1), electronic circuits adapted to control and drive the electric motor, a connector assembly (19) having conducting tracks (20) connecting the motor (1) to the electronic  
30 circuits, the gearbox (2) and a torque sensor.

23. An electric power assisted steering system according to claim 22, characterised in that the housing (3) is of metal.
- 5 24. An electric power assisted steering system according to claim 22 characterised in that the housing is of plastics material.
25. An electric power assisted steering system according to claim 22 or claim 24, characterised in that the housing comprises three integral  
10 portions; a first portion which houses the electronic circuits, a second portion which houses the part of the motor comprising a stator and an armature and accommodates a connector assembly, the second portion being sealed with an end cap, and a third portion which houses the gearbox and the torque sensor.
- 15 26. An electric power assisted steering system according to claim 25, characterised in that the second portion forms at least a part of the casing for the electric motor.
- 20 27. An electric power assisted steering system according to any one of claims 25 or 26 characterised in that the first, second or third portions define compartments which are isolated from one another in use.

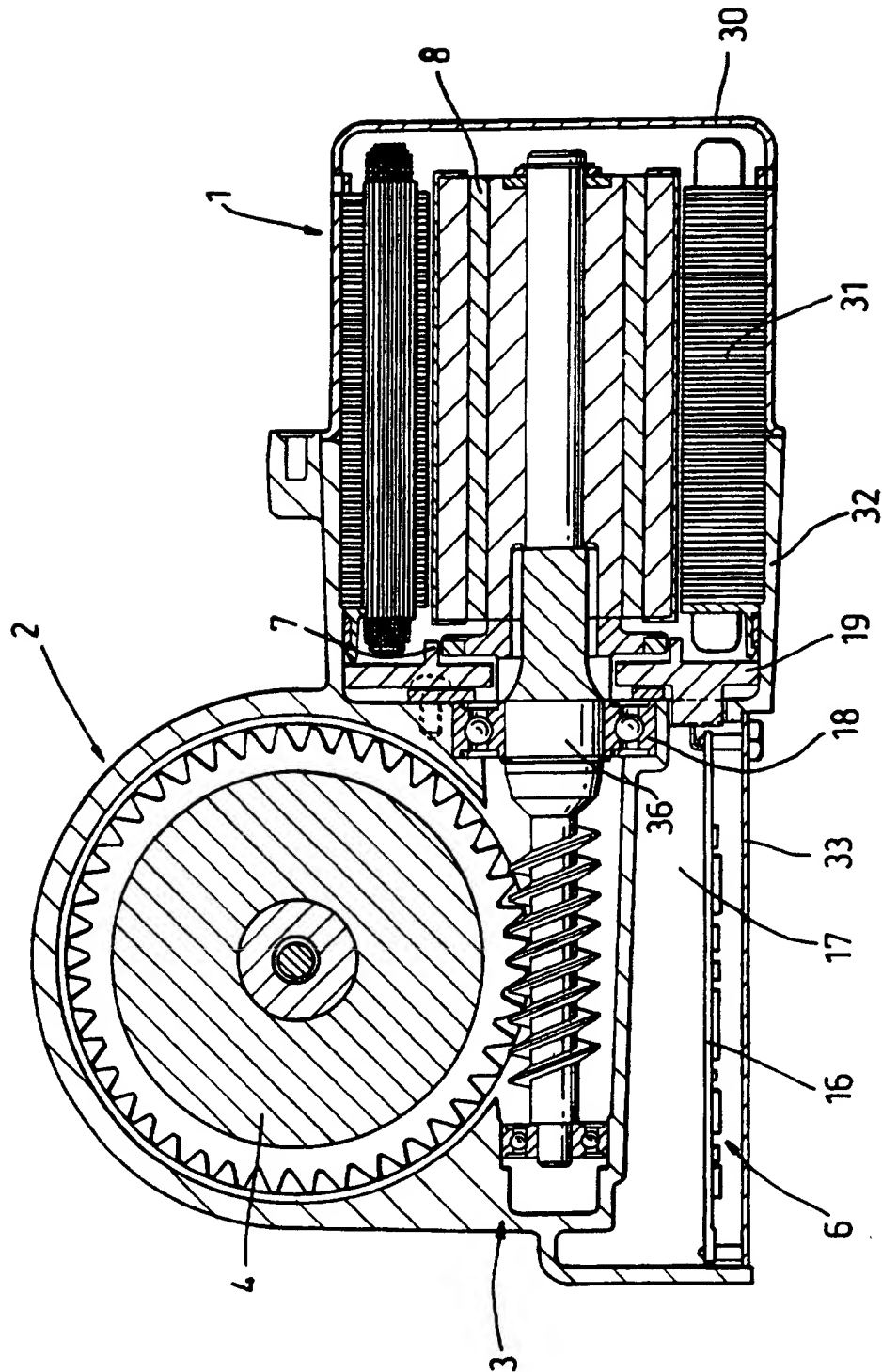


Fig. 1



217

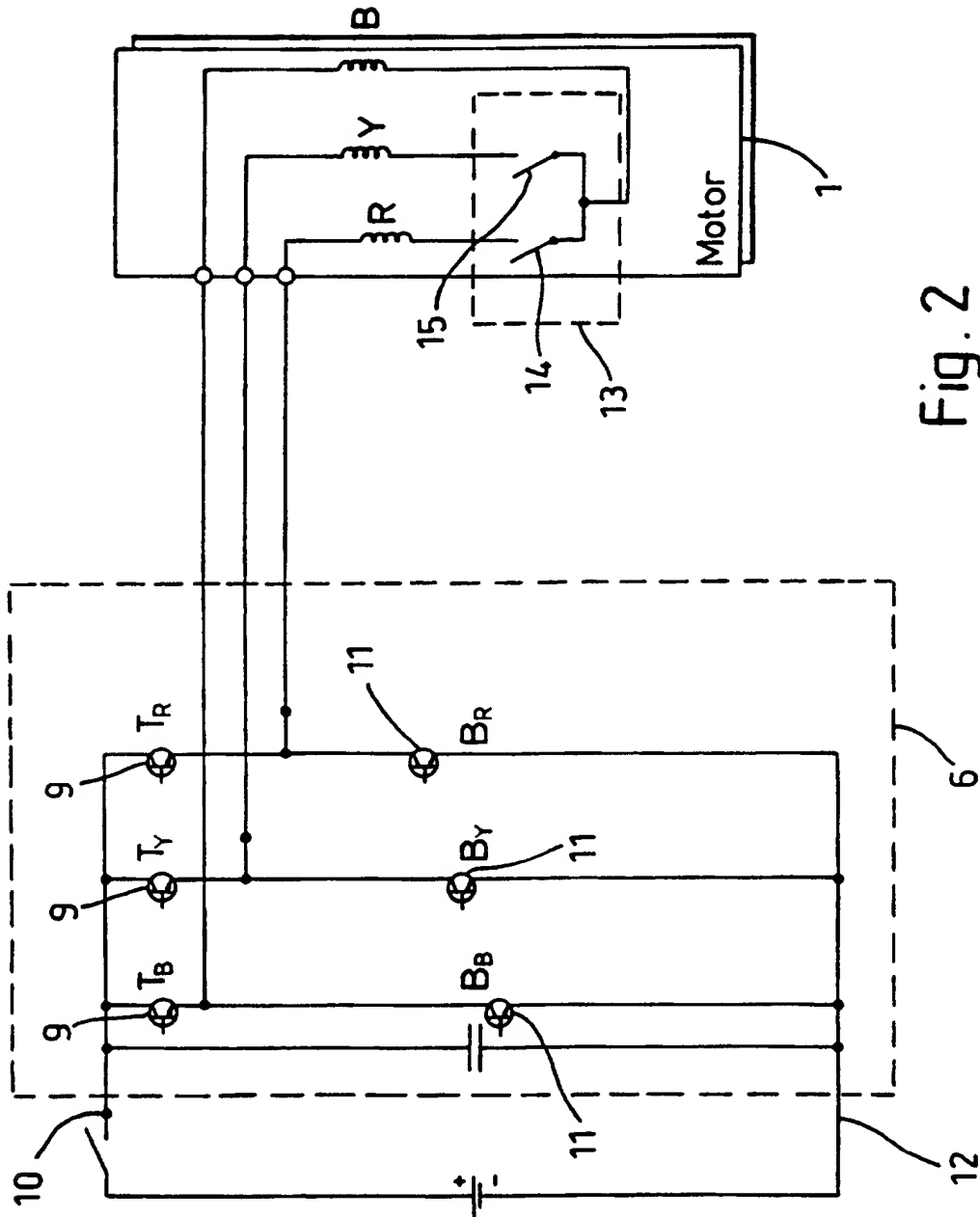


Fig. 2

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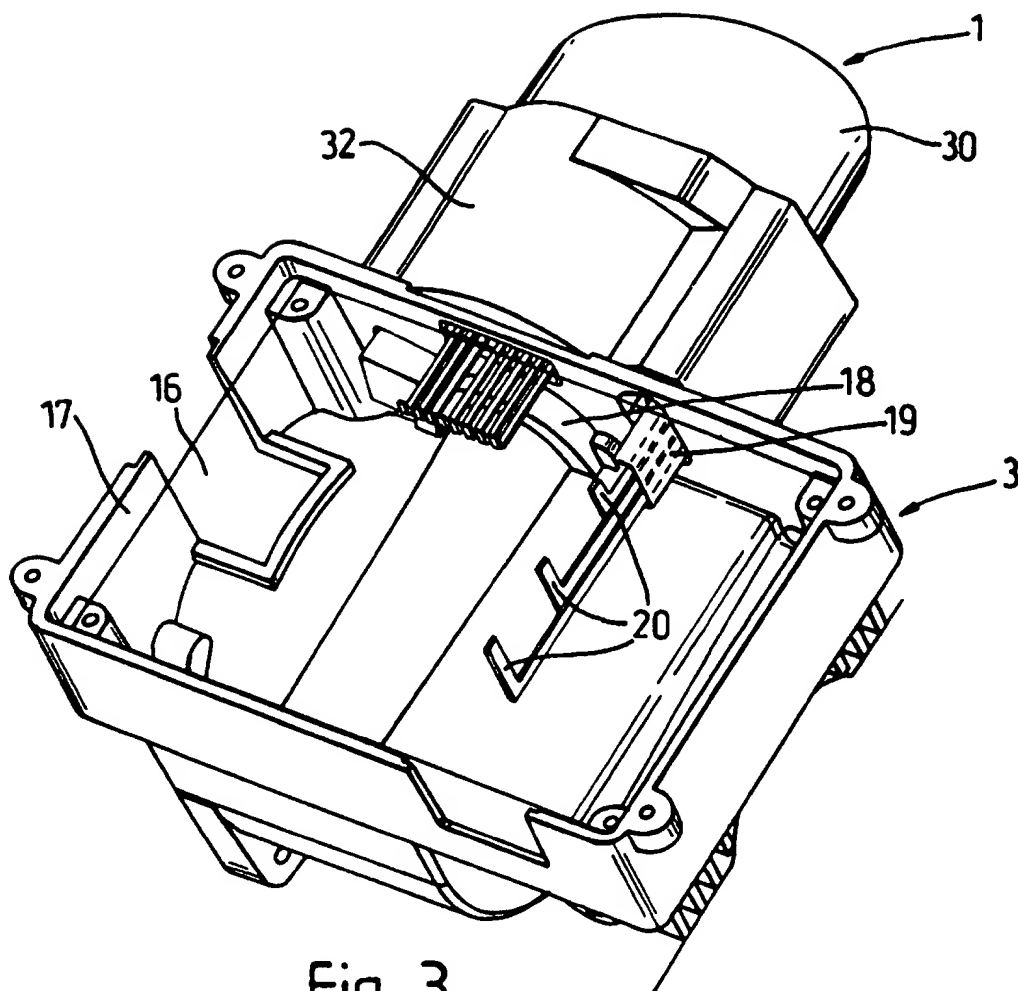


Fig. 3

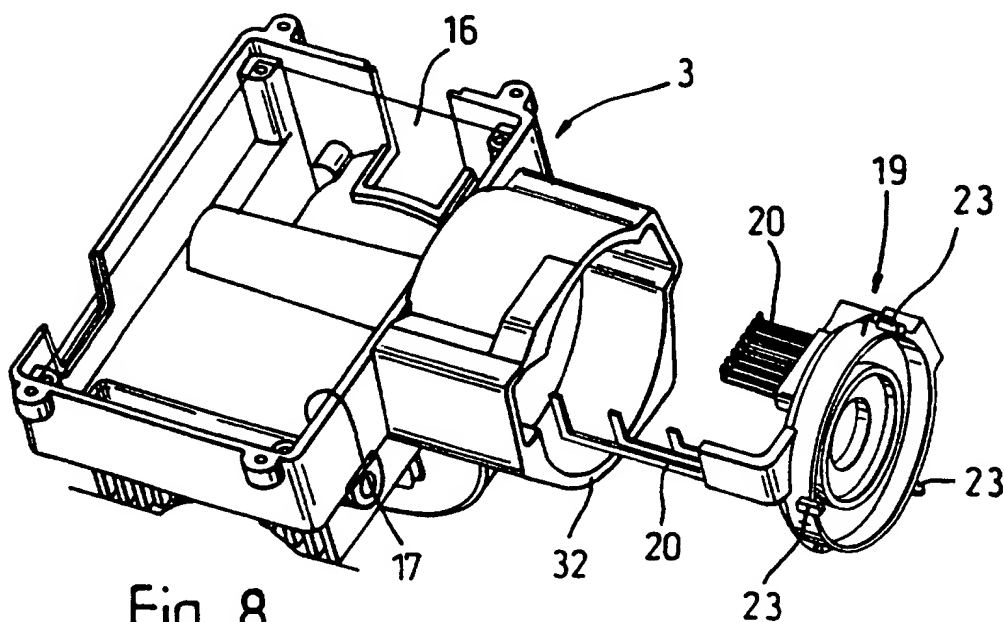


Fig. 8

SUBSTITUTE SHEET (RULE 26)

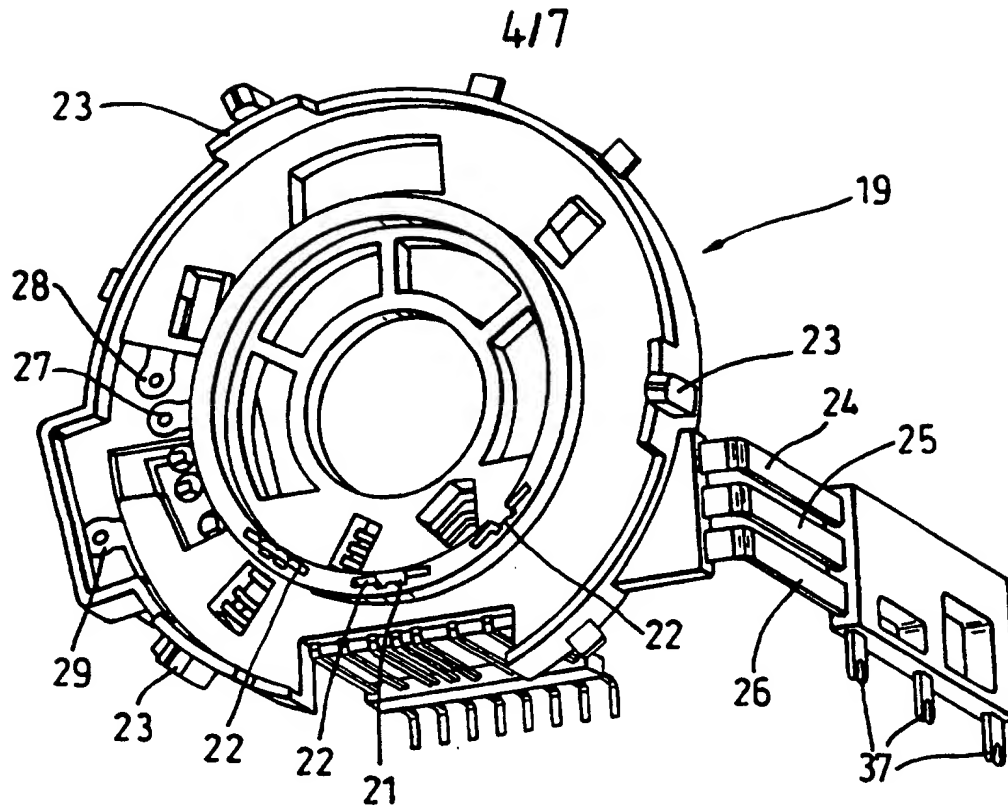


Fig. 4

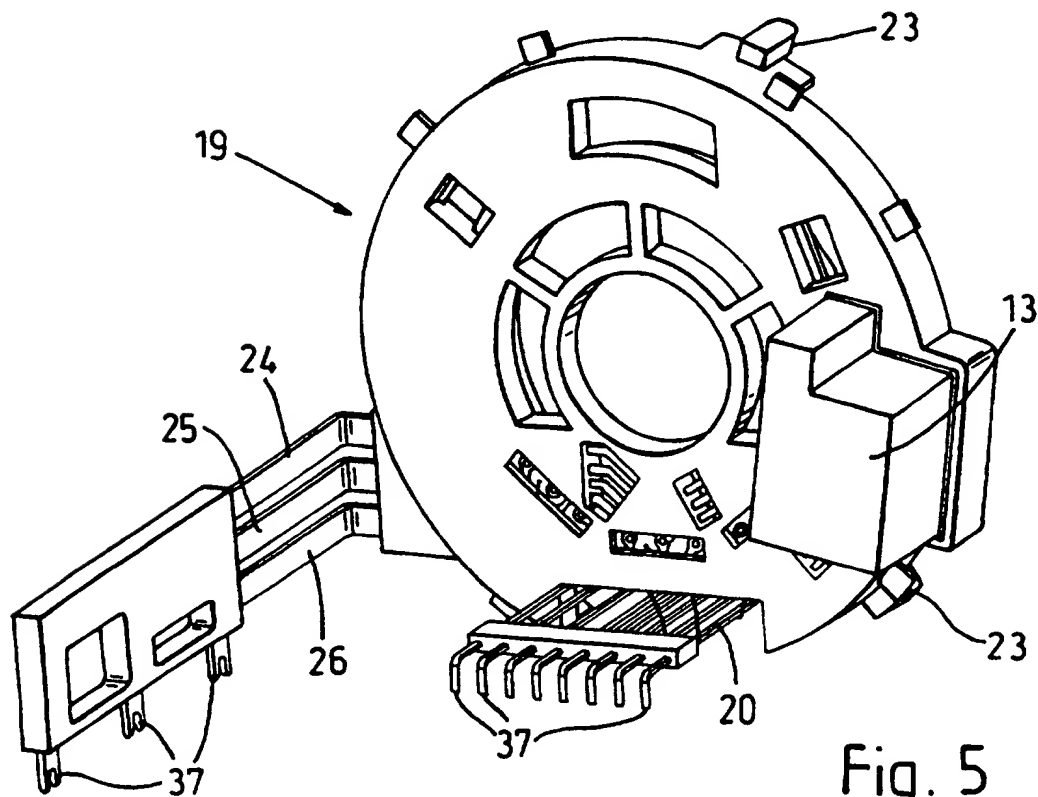
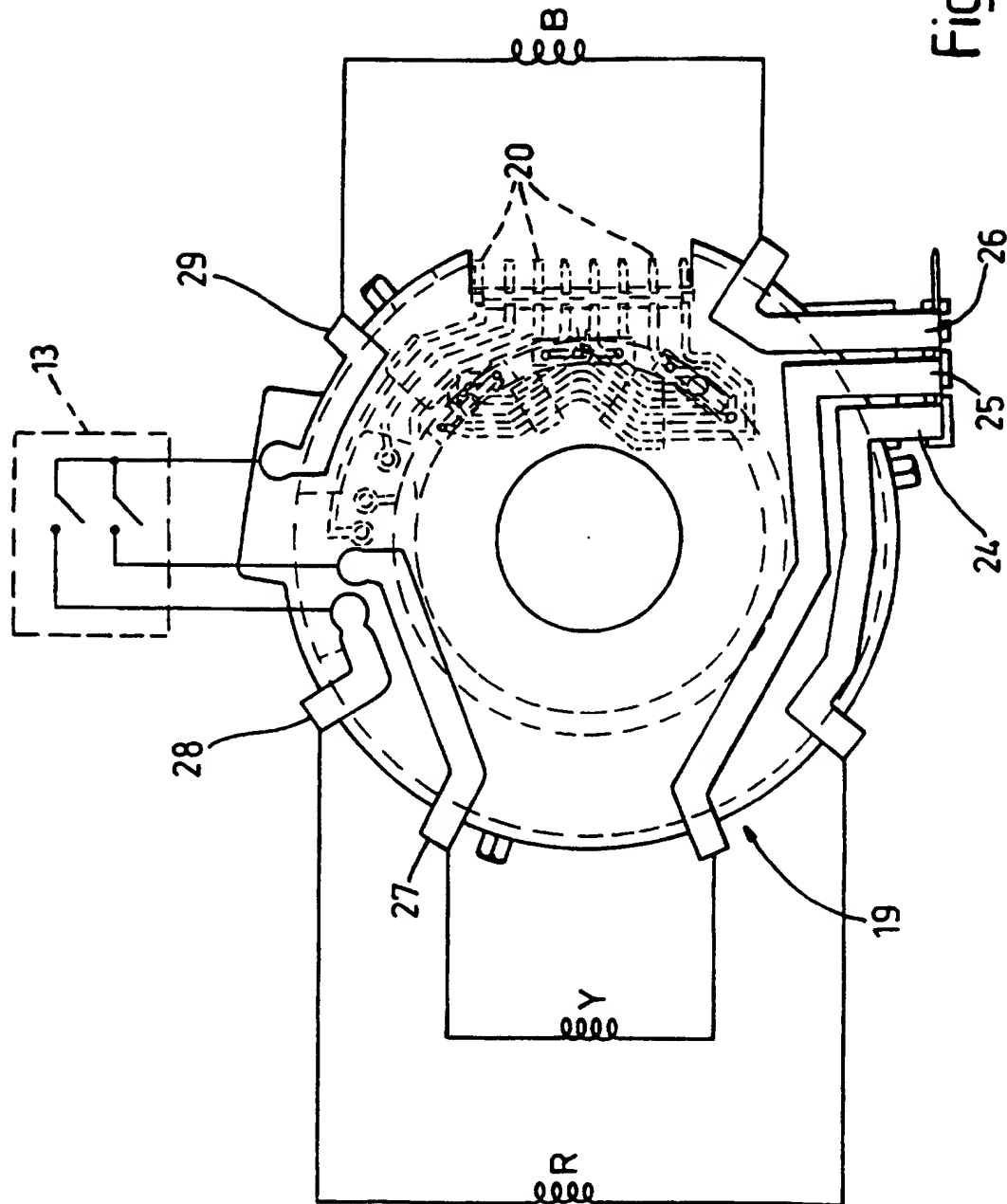


Fig. 5

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Fig. 6



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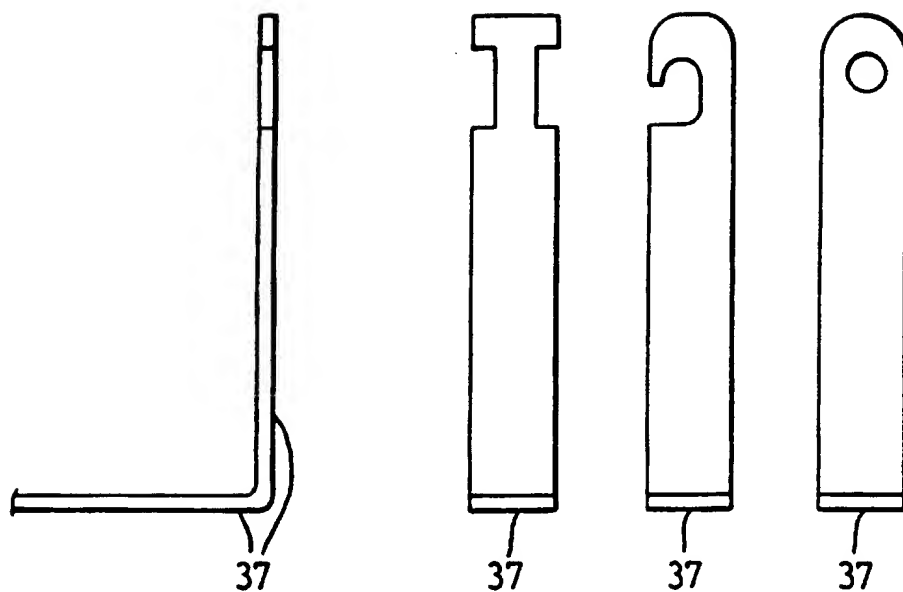


Fig. 7

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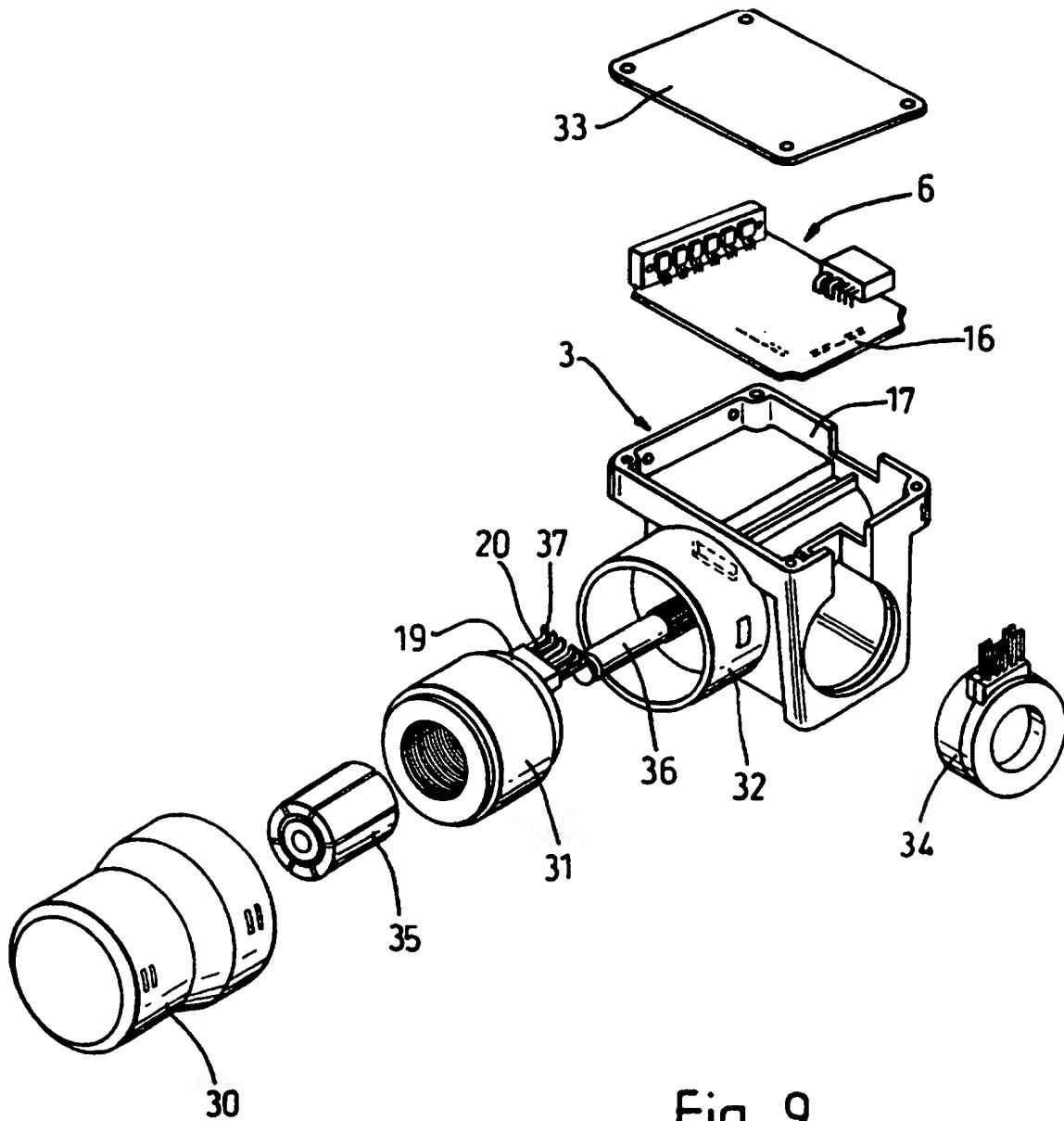


Fig. 9

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# INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 97/02446

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 B62D5/04 H02K11/00 H02K5/22

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 B62D H02K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication where appropriate, of the relevant passages	Relevant to claim No
A	EP 0 508 250 A (KOYO SEIKO CO) 14 October 1992 see column 3, line 22 - column 5, line 22; figures 4-6	1
A	GB 2 188 599 A (HONDA MOTOR CO LTD) 7 October 1987 see abstract; figure 2	1
X	GB 2 297 067 A (KAYABA INDUSTRY CO LTD) 24 July 1996 see page 3, line 31 - page 6, line 34; figures 1,2	7
A		11,15, 16,22



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

### Special categories of cited documents:

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- "&" document member of the same patent family

Date of the actual completion of the international search

7 January 1998

Date of mailing of the international search report

13/01/1998

Name and mailing address of the ISA

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Fax: (+31-70) 340-3016

Authorized officer

Kulozik, E

# INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 97/02446

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No
Y	CONNOR B: "ELEKTRISCHE LENKHILFEN FUR PKW ALS ALTERNATIVE ZU HYDRAULISCHEN UND ELEKTROHYDRAULISCHEN SYSTEMEN ELECTRIC POWER ASSISTED STEERING - AN ALTERNATIVE TO HYDRAULIC AND ELECTRO-HYDRAULIC SYSTEMS" ATZ AUTOMOBILTECHNISCHE ZEITSCHRIFT, vol. 98, no. 7/08, 1 July 1996, pages 406-408, 410, XP000599773 see page 407, left-hand column, paragraph 2; figures 1-3	22,23, 25,26
A	---	7,11,14, 26
P,X	WO 97 18119 A (LUCAS IND PLC ;COLES JEFF RONALD (GB); JOHNSON ANTHONY (GB); WILKE) 22 May 1997 see page 9, line 10 - line 16; figure 6	7,8, 10-12, 14,18-20
P,Y	-----	22,23, 25,26



# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/GB 97/02446

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0508250 A	14-10-92	JP 4306170 A	28-10-92
		DE 69200673 D	22-12-94
		DE 69200673 T	16-03-95
		US 5255755 A	26-10-93
GB 2188599 A	07-10-87	JP 7096387 B	18-10-95
		JP 62231871 A	12-10-87
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		FR 2729629 A	26-07-96
WO 9718119 A	22-05-97	WO 9718120 A	22-05-97

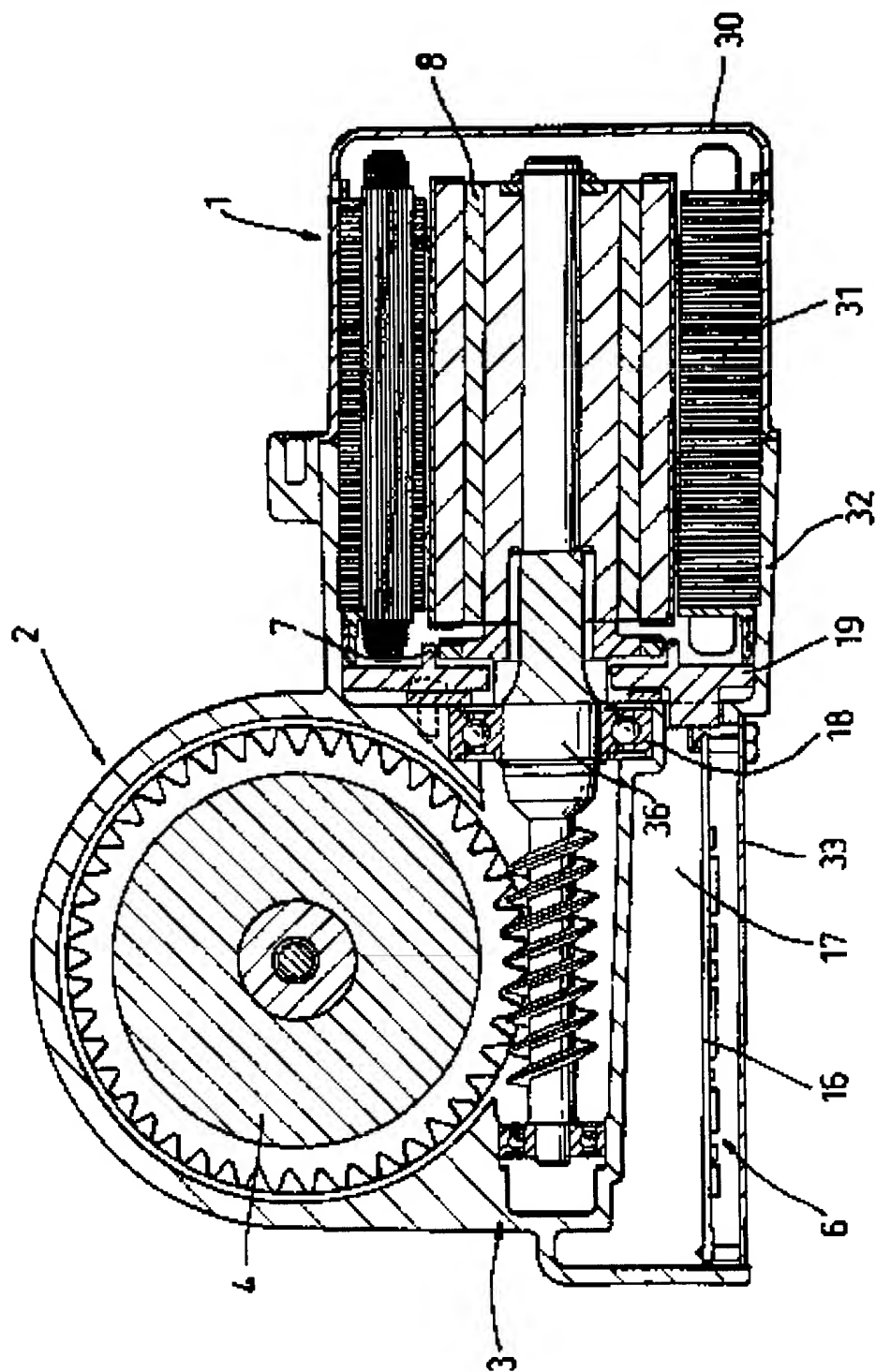


Fig. 1

217

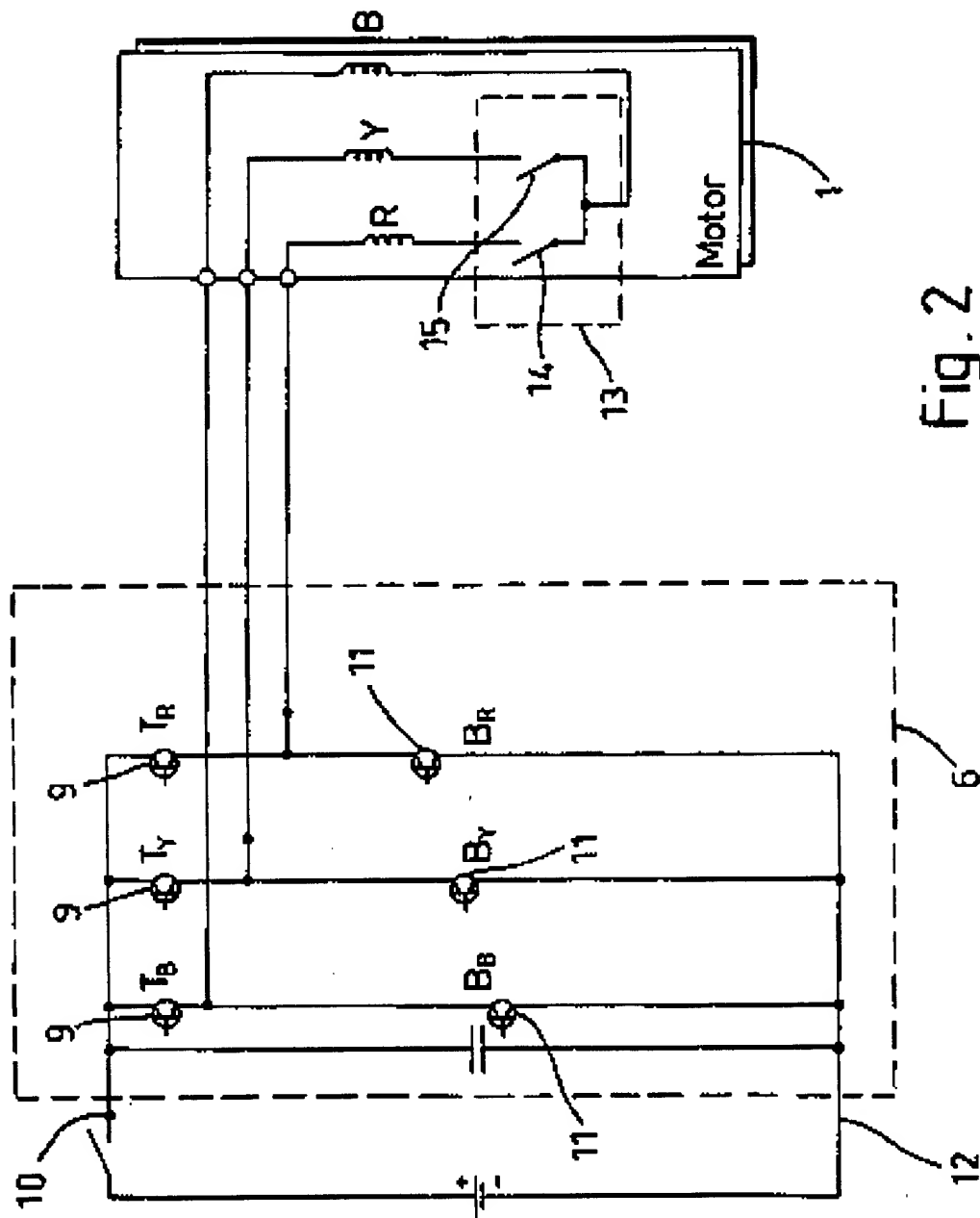


Fig. 2

3/7

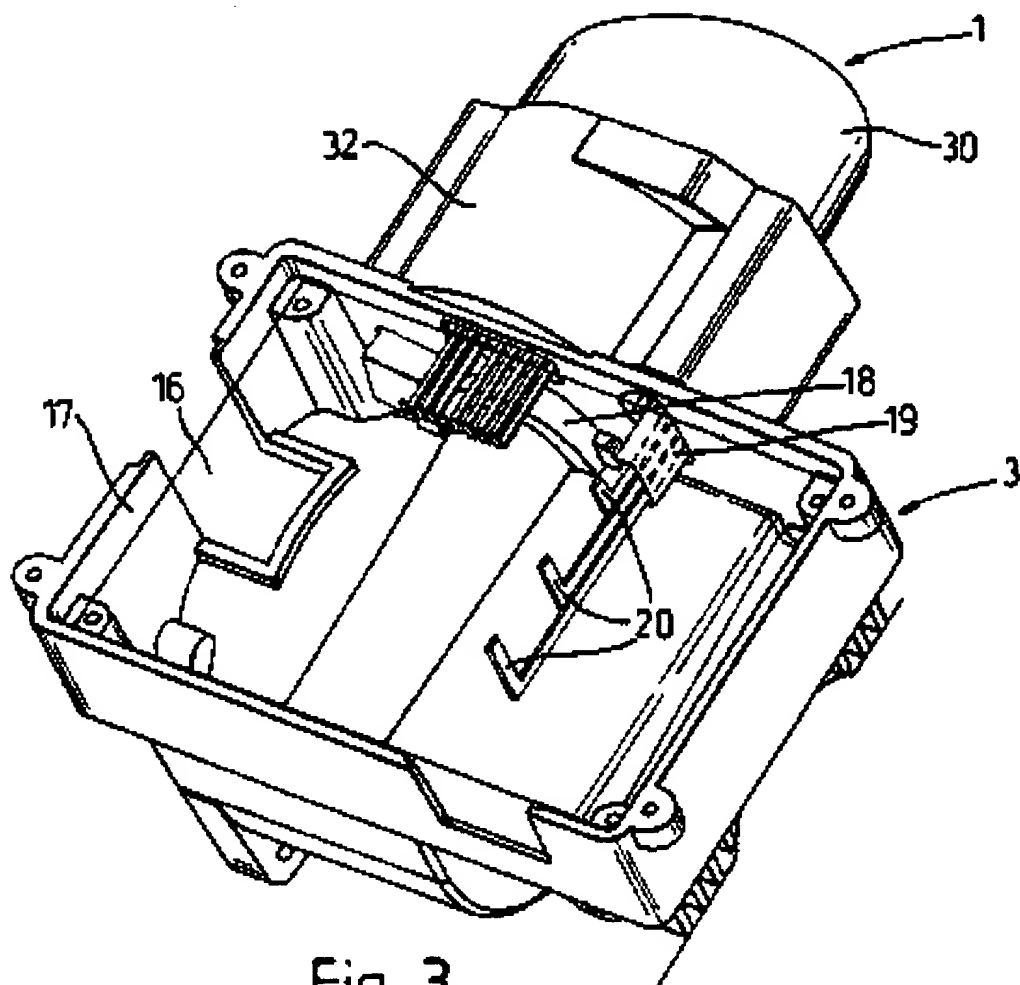


Fig. 3

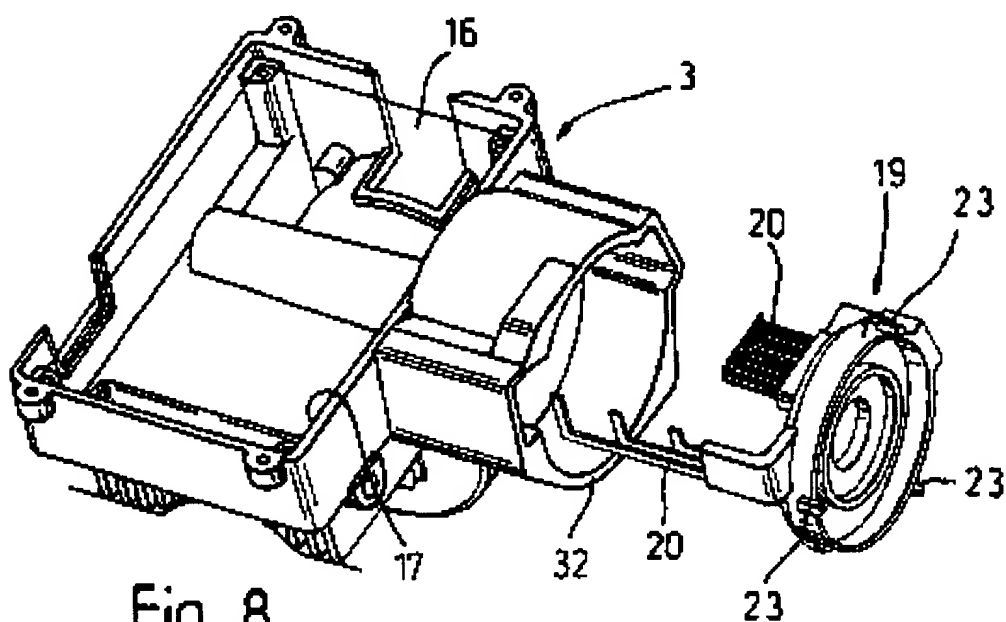


Fig. 8

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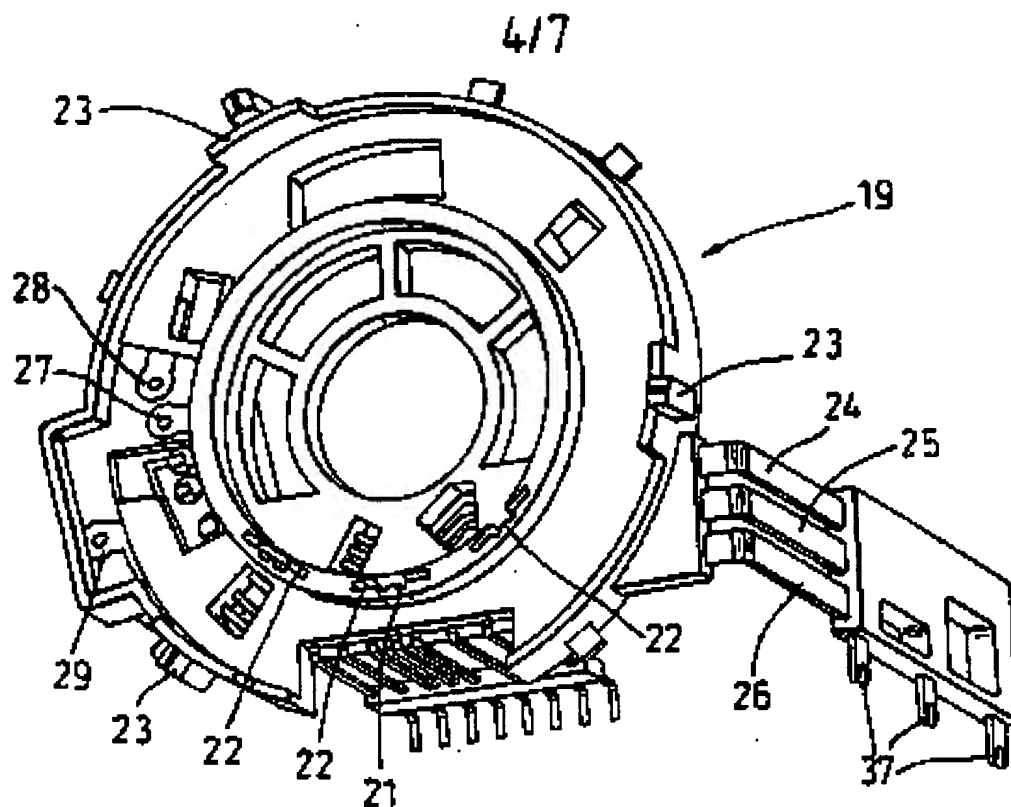


Fig. 4

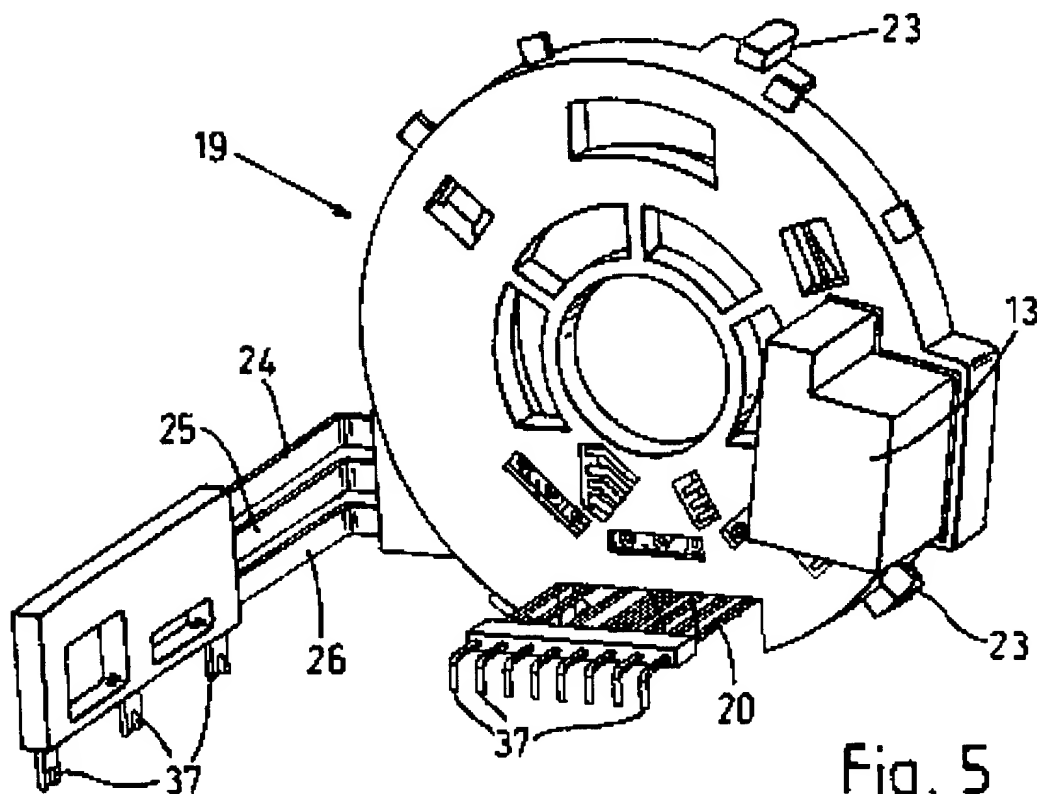
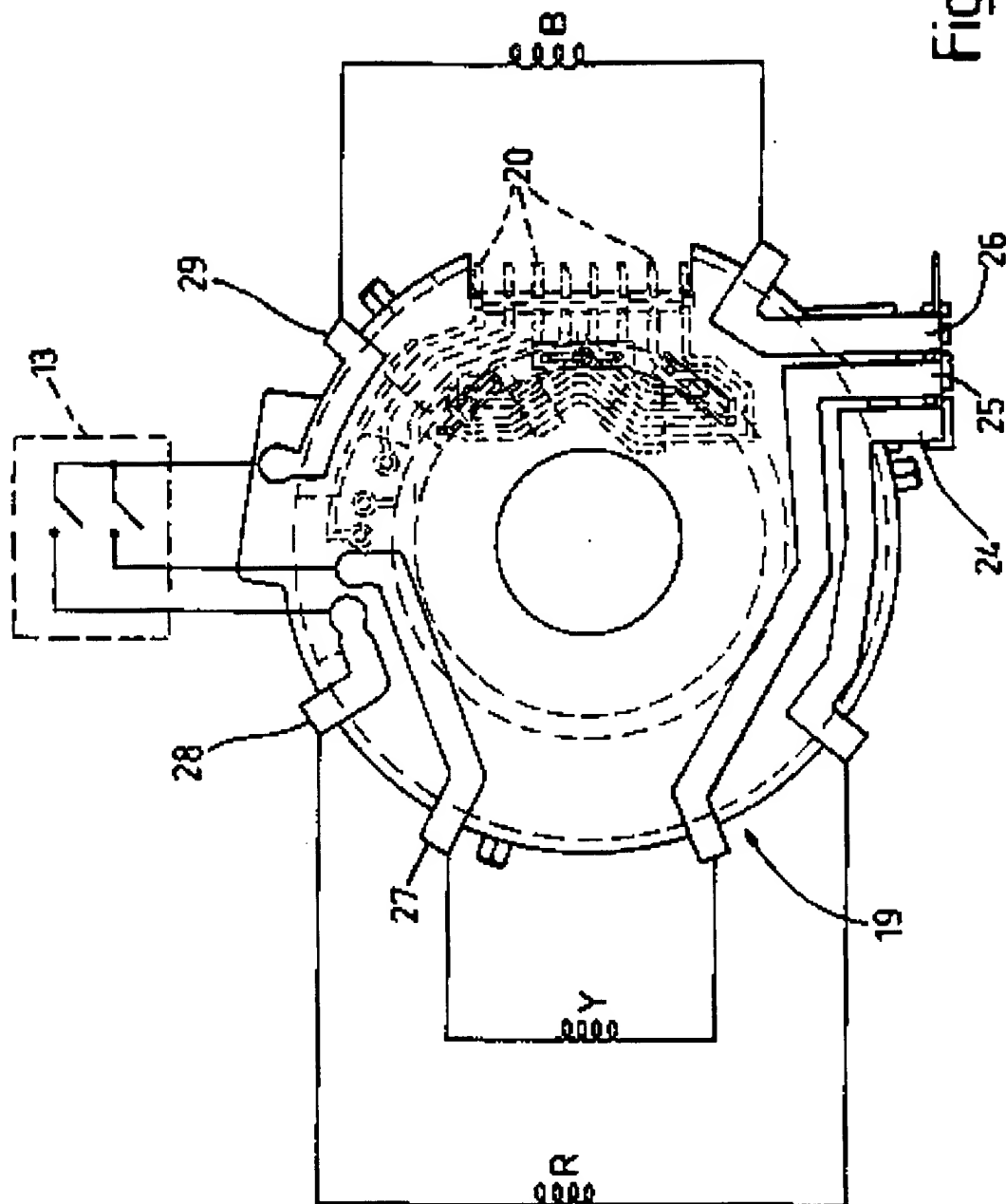


Fig. 5

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5/7

Fig. 6



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617

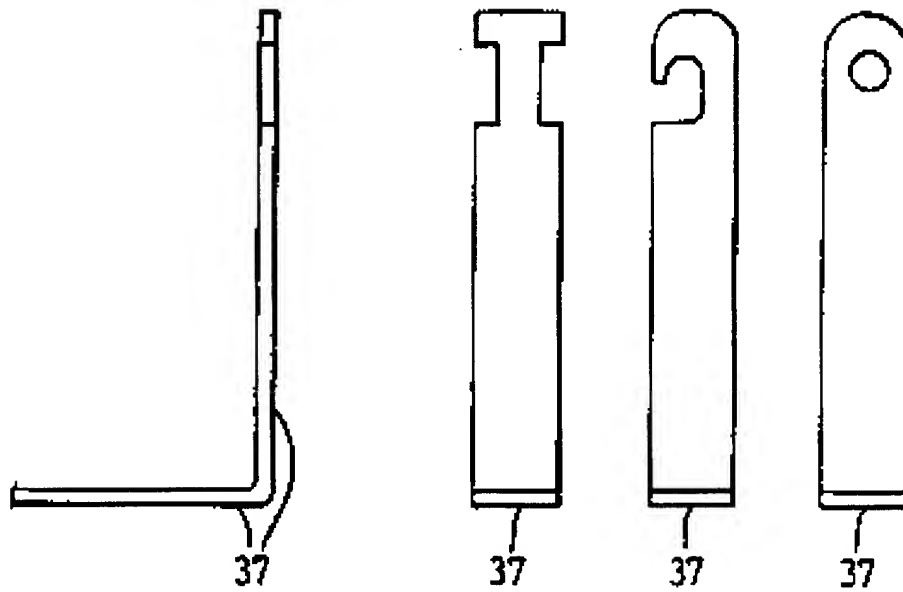


Fig. 7

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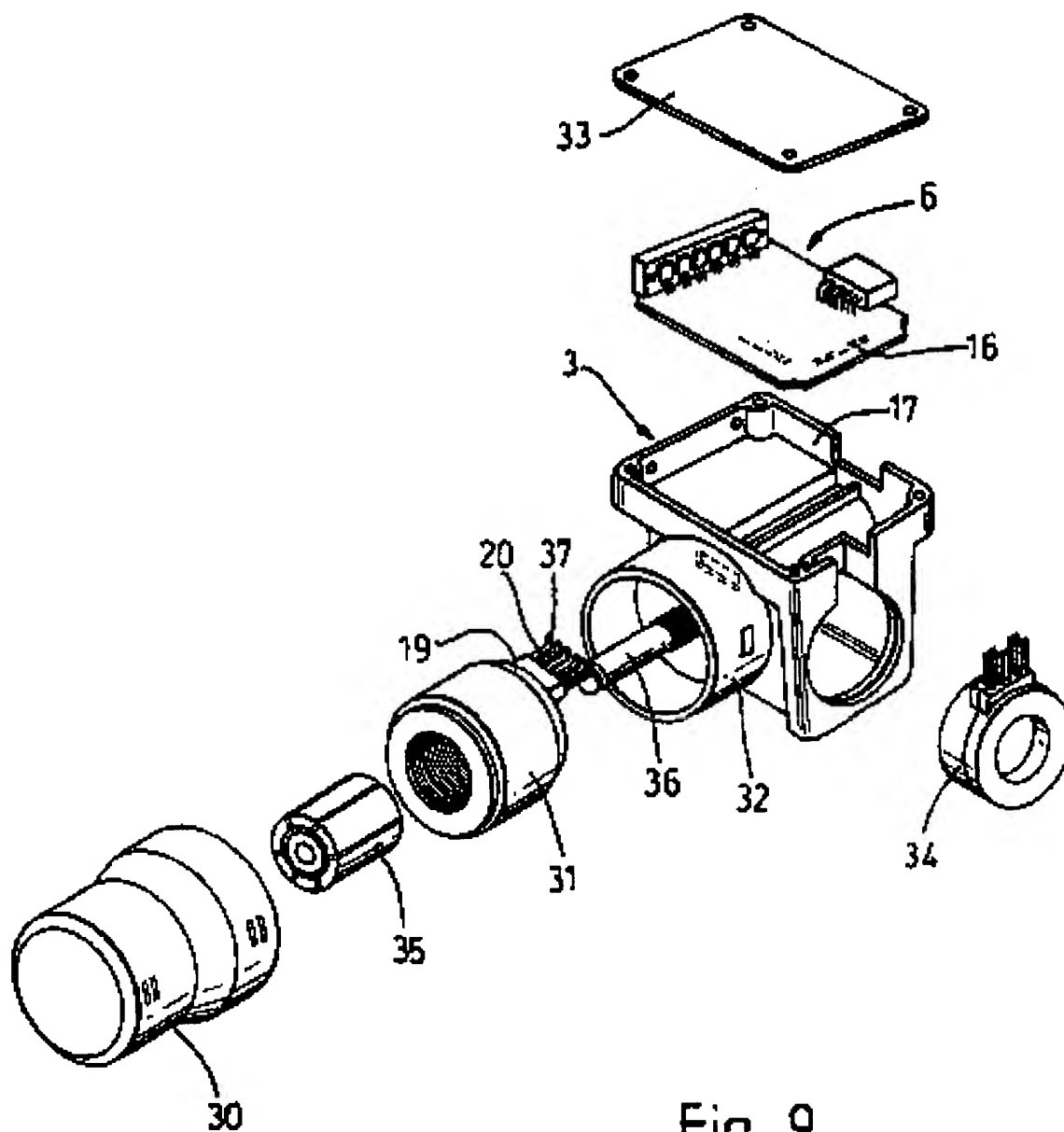


Fig. 9

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# PCT

## INTERNATIONALER RECHERCHENBERICHT

(Artikel 18 sowie Regeln 43 und 44 PCT)

Aktenzeichen des Anmelders oder Anwalts <b>R. 37638-1 Rs/Hx</b>	<b>WEITERES VORGEHEN</b> siehe Mitteilung über die Übermittlung des internationalen Recherchenberichts (Formblatt PCT/ISA/220) sowie, soweit zutreffend, nachstehender Punkt 5	
Internationales Aktenzeichen <b>PCT/DE 01/ 00592</b>	Internationales Anmeldedatum (Tag/Monat/Jahr) <b>16/02/2001</b>	(Frühestes) Prioritätsdatum (Tag/Monat/Jahr) <b>01/03/2000</b>
Anmelder  <b>ROBERT BOSCH GMBH et al.</b>		

Dieser internationale Recherchenbericht wurde von der Internationalen Recherchenbehörde erstellt und wird dem Anmelder gemäß Artikel 18 übermittelt. Eine Kopie wird dem Internationalen Büro übermittelt.

Dieser internationale Recherchenbericht umfaßt insgesamt 3 Blätter.

☒ Darüber hinaus liegt ihm jeweils eine Kopie der in diesem Bericht genannten Unterlagen zum Stand der Technik bei.

### 1. Grundlage des Berichts

a. Hinsichtlich der **Sprache** ist die internationale Recherche auf der Grundlage der internationalen Anmeldung in der Sprache durchgeführt worden, in der sie eingereicht wurde, sofern unter diesem Punkt nichts anderes angegeben ist.

☐ Die internationale Recherche ist auf der Grundlage einer bei der Behörde eingereichten Übersetzung der internationalen Anmeldung (Regel 23.1 b)) durchgeführt worden.

b. Hinsichtlich der in der internationalen Anmeldung offenbarten **Nucleotid- und/oder Aminosäuresequenz** ist die internationale Recherche auf der Grundlage des Sequenzprotokolls durchgeführt worden, das

☐ in der internationalen Anmeldung in schriftlicher Form enthalten ist.

☐ zusammen mit der internationalen Anmeldung in computerlesbarer Form eingereicht worden ist.

☐ bei der Behörde nachträglich in schriftlicher Form eingereicht worden ist.

☐ bei der Behörde nachträglich in computerlesbarer Form eingereicht worden ist.

☐ Die Erklärung, daß das nachträglich eingereichte schriftliche Sequenzprotokoll nicht über den Offenbarungsgehalt der internationalen Anmeldung im Anmeldezeitpunkt hinausgeht, wurde vorgelegt.

☐ Die Erklärung, daß die in computerlesbarer Form erfaßten Informationen dem schriftlichen Sequenzprotokoll entsprechen, wurde vorgelegt.

2. ☐ Bestimmte Ansprüche haben sich als nicht recherchierbar erwiesen (siehe Feld I).

3. ☐ Mangelnde Einheitlichkeit der Erfindung (siehe Feld II).

### 4. Hinsichtlich der Bezeichnung der Erfindung

☐ wird der vom Anmelder eingereichte Wortlaut genehmigt.

☒ wurde der Wortlaut von der Behörde wie folgt festgesetzt:

**FAIL-SAFE FÜR BÜRSTENLOSE GLEICHSTROMANTRIEBE.**

### 5. Hinsichtlich der Zusammenfassung

☒ wird der vom Anmelder eingereichte Wortlaut genehmigt.

☐ wurde der Wortlaut nach Regel 38.2b) in der in Feld III angegebenen Fassung von der Behörde festgesetzt. Der Anmelder kann der Behörde innerhalb eines Monats nach dem Datum der Absendung dieses internationalen Recherchenberichts eine Stellungnahme vorlegen.

6. Folgende Abbildung der **Zeichnungen** ist mit der Zusammenfassung zu veröffentlichen: Abb. Nr. 4

☐ wie vom Anmelder vorgeschlagen

☐ keine der Abb.

☐ weil der Anmelder selbst keine Abbildung vorgeschlagen hat.

☒ weil diese Abbildung die Erfindung besser kennzeichnet.

## A. KLASSIFIZIERUNG DES ANMELDUNGSGEGENSTANDES

IPK 7 H02K11/00 H02K3/28 H02H7/08 B62D5/04 B60R16/02

Nach der Internationalen Patentklassifikation (IPK) oder nach der nationalen Klassifikation und der IPK

## B. RECHERCHIERTE GEBIETE

Recherchierter Mindestprüfstoff (Klassifikationssystem und Klassifikationssymbole)

IPK 7 H02K H02H B62D B60L B60R

Recherchierte aber nicht zum Mindestprüfstoff gehörende Veröffentlichungen, soweit diese unter die recherchierten Gebiete fallen

Während der internationalen Recherche konsultierte elektronische Datenbank (Name der Datenbank und evtl. verwendete Suchbegriffe)

EPO-Internal, PAJ, WPI Data

## C. ALS WESENTLICH ANGESEHENE UNTERLAGEN

Kategorie*	Bezeichnung der Veröffentlichung, soweit erforderlich unter Angabe der in Betracht kommenden Teile	Betr. Anspruch Nr.
X	WO 98 10971 A (APPLEYARD MICHAEL ; IRONSIDE JOHN MICHAEL (GB); WILKES MARK ANTHONY) 19. März 1998 (1998-03-19)	1,2, 10-12
Y	Seite 11, Zeile 22 - Seite 12, Zeile 2; Ansprüche 1,2,5,6; Abbildung 2 ---	1,3,4,9, 13
Y	DE 44 06 730 A (BAYERN CHEMIE GMBH FLUGCHEMIE) 14. September 1995 (1995-09-14) Spalte 2, Zeile 45 - Zeile 64; Anspruch 1; Abbildung 1 ---	1,3,4
Y	PATENT ABSTRACTS OF JAPAN vol. 017, no. 630 (E-1463), 22. November 1993 (1993-11-22) -& JP 05 199712 A (SHIBAURA ENG WORKS CO LTD), 6. August 1993 (1993-08-06) Zusammenfassung; Abbildungen 1,2 ---	9
	--- -/--	



Weitere Veröffentlichungen sind der Fortsetzung von Feld C zu entnehmen



Siehe Anhang Patentfamilie

\* Besondere Kategorien von angegebenen Veröffentlichungen :

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\*L\* Veröffentlichung, die geeignet ist, einen Prioritätsanspruch zweifelhaft erscheinen zu lassen, oder durch die das Veröffentlichungsdatum einer anderen im Recherchenbericht genannten Veröffentlichung belegt werden soll oder die aus einem anderen besonderen Grund angegeben ist (wie ausgeführt)

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Datum des Abschlusses der internationalen Recherche

18. Mai 2001

Absendedatum des internationalen Recherchenberichts

30/05/2001

Name und Postanschrift der Internationalen Recherchenbehörde

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Fax: (+31-70) 340-3016

Bevollmächtigter Bediensteter

von Rauch, E

## C.(Fortsetzung) ALS WESENTLICH ANGESEHENE UNTERLAGEN

Kategorie°	Bezeichnung der Veröffentlichung, soweit erforderlich unter Angabe der in Betracht kommenden Teile	Betr. Anspruch Nr.
Y	GB 743 765 A (WESTINGHOUSE ELECTRIC INTERNAT) 25. Januar 1956 (1956-01-25)	13
A	Seite 3, Zeile 53 -Seite 4, Zeile 27; Ansprüche 1,2; Abbildungen 3,4 ---	8,12
X	PATENT ABSTRACTS OF JAPAN vol. 1998, no. 08, 30. Juni 1998 (1998-06-30) -& JP 10 075596 A (JIDOSHA KIKI CO LTD), 17. März 1998 (1998-03-17)	1,2,14
A	Zusammenfassung; Abbildungen 1,4,6 ---	15
X	EP 0 508 250 A (KOYO SEIKO CO) 14. Oktober 1992 (1992-10-14)	1,2,10, 11
A	Spalte 4, Zeile 45 -Spalte 5, Zeile 12; Anspruch 1; Abbildungen 4,5 ---	14,15
A	US 4 833 387 A (PFEIFFER RUEDIGER) 23. Mai 1989 (1989-05-23) Spalte 1, Zeile 63 -Spalte 2, Zeile 2; Anspruch 1; Abbildung 1 ---	14,15
A	DE 42 09 167 A (SIEMENS AG) 23. September 1993 (1993-09-23) Spalte 3, Zeile 60 -Spalte 4, Zeile 22; Anspruch 1; Abbildungen 2-10 -----	14

# INTERNATIONAL SEARCH REPORT

Informal patent family members

Internal Application No

PCT/ 01/00592

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9810971 A	19-03-1998	BR 9706747 A EP 0857135 A JP 2000500102 T US 6194849 B US 6211631 B	20-07-1999 12-08-1998 11-01-2000 27-02-2001 03-04-2001
DE 4406730 A	14-09-1995	NONE	
JP 05199712 A	06-08-1993	NONE	
GB 743765 A	25-01-1956	NONE	
JP 10075596 A	17-03-1998	NONE	
EP 0508250 A	14-10-1992	JP 4306170 A DE 69200673 D DE 69200673 T US 5255755 A	28-10-1992 22-12-1994 16-03-1995 26-10-1993
US 4833387 A	23-05-1989	DE 3709168 A DE 3877790 A EP 0282764 A ES 2038221 T ZA 8801349 A	29-09-1988 11-03-1993 21-09-1988 16-07-1993 29-08-1988
DE 4209167 A	23-09-1993	NONE	

Patent Abstracts of Japan

PUBLICATION NUMBER : 05199712  
PUBLICATION DATE : 06-08-93

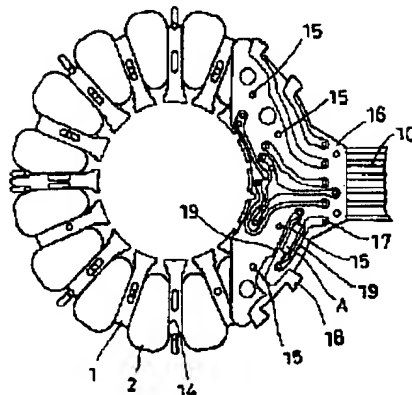
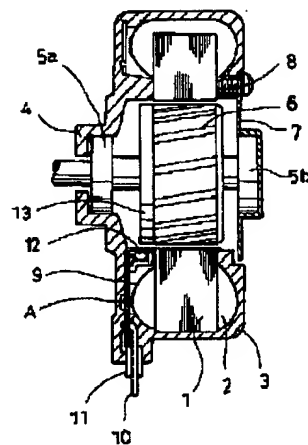
APPLICATION DATE : 20-01-92  
APPLICATION NUMBER : 04007864

APPLICANT : SHIBAURA ENG WORKS CO LTD;

INVENTOR : YUNOKI YASUNOBU;

INT.CL. : H02K 11/00

TITLE : MOTOR



ABSTRACT : PURPOSE: To obtain a molded motor in which a danger such as an ignition, etc., can be prevented by providing a temperature fuse in the vicinity of extrafine wirings to generate heat by an overcurrent formed part of printed wirings for connecting a power source to a winding.

CONSTITUTION: A winding 2 of a motor is wired via a printed board 9 buried in a frame 3. Leads 10 are connected to the board 9, and extended out of the frame 3 by a bushing 11. Two extrafine wirings 12 formed fine than other printed wirings are formed in parallel between a terminal 17 connected with a power source and a terminal 18 connected with the winding 2, and a temperature fuse A is provided between the wirings 19. If an overcurrent flows to the winding 2 of the motor, the wirings 19 on the board 9 generate heat due to an electric resistance. When the fuse A reaches a predetermined temperature, its interior is shut OFF to open between the terminal 17 connected with the power source and the terminal 18 connected with the winding.

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Patent Abstracts of Japan

PUBLICATION NUMBER : 10075596  
PUBLICATION DATE : 17-03-98

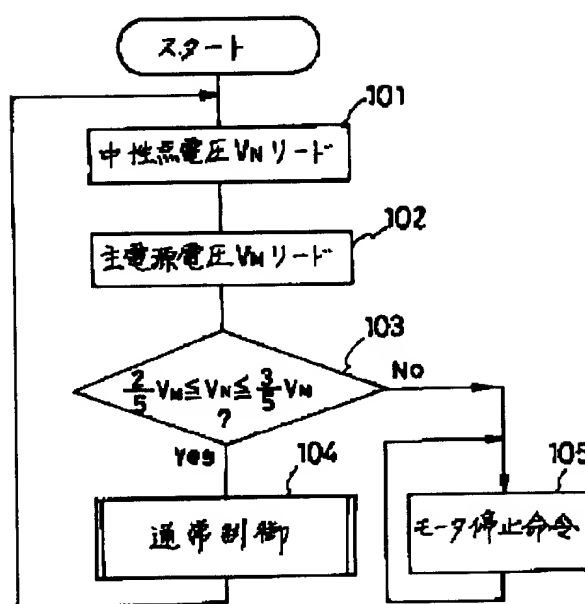
APPLICATION DATE : 29-08-96  
APPLICATION NUMBER : 08228207

APPLICANT : JIDOSHA KIKI CO LTD;

INVENTOR : WATANABE MASANORI;

INT.CL. : H02P 6/12 B62D 5/04 B62D 6/00

TITLE : METHOD FOR DETECTING  
ABNORMALITY OF BRUSHLESS  
MOTOR



ABSTRACT : PROBLEM TO BE SOLVED: To detect the abnormality of a brushless motor, such as the disconnection, ground-fault, etc., of driving coils with a simple inexpensive circuit configuration and, at the same time, to detect the ground-fault of the coils before conduction.

SOLUTION: The voltage VN at the neutral point of the starconnected driving coils of a brushless motor is read (step 101) and the main power supply voltage VM to the brushless motor is read (step 102). Then whether or not a conditional expression,  $(2/5)V_N \leq V_N \leq (3/5)V_N$  is checked, namely, whether or not the voltage VN at the neutral point falls within the range of 40-60 % of the main power supply voltage V is checked (step 103). When the voltage VN falls within the range, the brushless motor is normally controlled (step 104). When the voltage VV does not fall within the range, the power supply to the motor is interrupted by sending a motor stopping instruction (step 105).

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